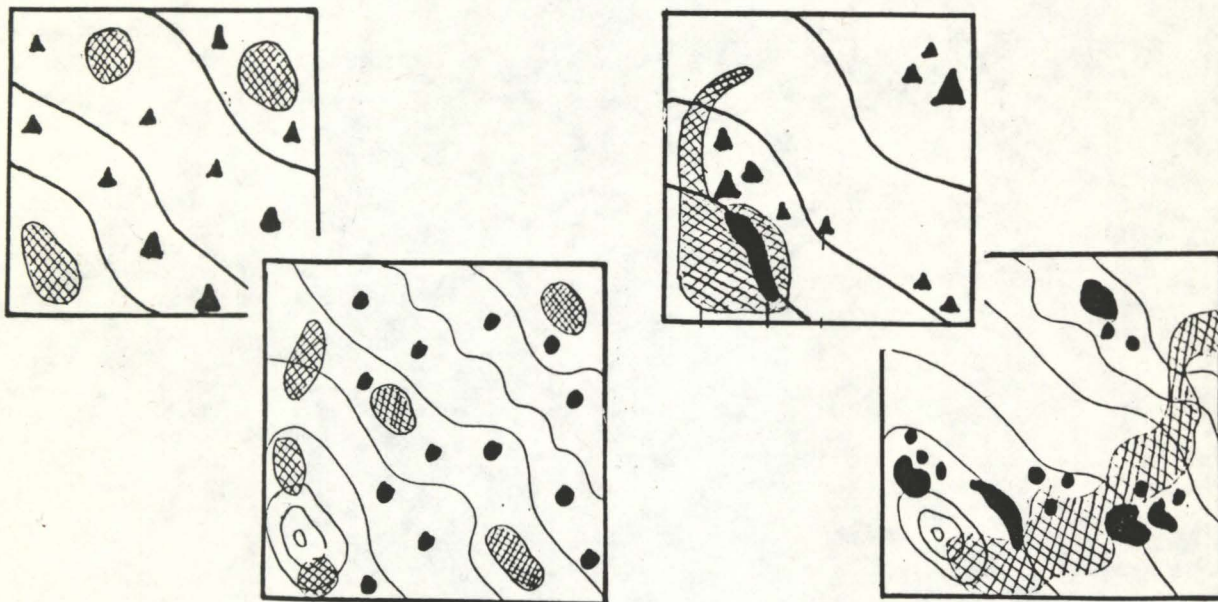


LANDSCAPE DESIGN GUIDELINES for RECLAIMED COAL-MINED LAND

ECOLOGICAL & VISUAL ATTRIBUTES of BIODIVERSITY



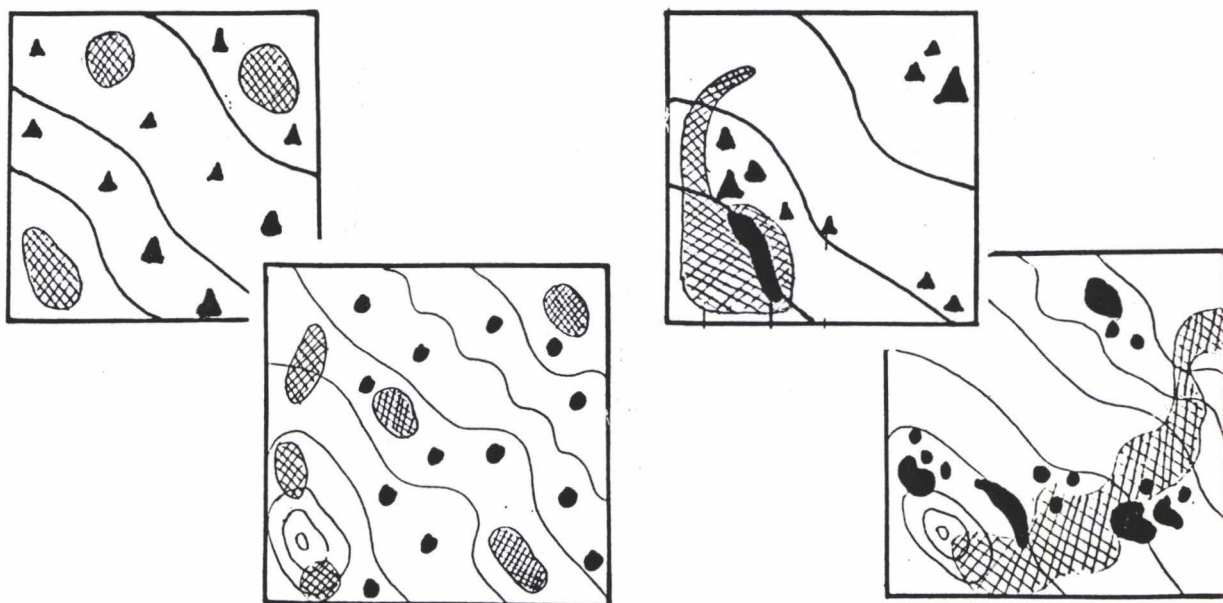
Thunder Basin National Grassland

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EXPERIMENT STATION

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TABLE OF CONTENTS

Introduction	1
Publications on post-mining landscape design and landscape characteristics.....	2
The <u>Land and Resource Management Plan</u> for the Medicine Bow National Forest and Thunder Basin National Grassland (1985).....	3
Location of the coal mining area.....	5
Forest Service Visual Quality Criteria.....	6
Landscape elements.....	7
Upland landform diversity.....	8
Riparian landform diversity.....	14
Riparian diversity design criteria.....	15
Geomorphic surfaces and vegetation biodiversity.....	17
Vegetation biodiversity and landscape design.....	20
Reclamation plan revegetation and design assessment criteria.....	26

INTRODUCTION

The reclamation of coal-mined land on the Thunder Basin National Grassland provides special opportunities to reconstruct landscapes that are ecologically functional and visually pleasing, using attributes of landforms, rock outcrops, riparian systems and vegetation appropriate to the vast, open landscape of east central Wyoming. The U.S. Forest Service has a long history of concern with functional and visual aspects of National Forest and National Grassland landscape management.

As a partner with private industry, in the reclamation process, the Forest Service can provide guidance for reclamation plan design which will satisfy the evaluation criteria in the Thunder Basin National Grassland Land and Resource Management Plan (1985) and the Forest Service Region 2 Regional Guide - 1991 revision. As reclamation plans are updated and revised in the 1990s in response to permit renewals, new coal leases and past experience, it is important that Forest Service guidelines, translated into landscape design attributes, be available to mine personnel responsible for developing reclamation concept plans presented for Forest Service consent.

This document presents reclamation criteria found in the Medicine Bow National Forest and Thunder Basin National Grassland Land and Resource Management Plan (1985). It also defines landscape attributes of the coal mining district of the Thunder Basin National Grassland. Design concepts compatible with the landscape and with the Forest Plan guidelines are presented. The intent is to suggest ecologically functional, and visually acceptable, landscape architectural features for reclamation plans, compatible with policies and guidelines in the Land and Resource Management Plan and Regional Guide.

All suggested activities must be accomplished within the requirements established by State and Federal Law.

Judy von Ahlefeldt

Ecologist
Douglas Ranger District
Thunder Basin National
Grassland
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April, 1991

"SUCCESSFUL MINED LAND RECLAMATION, PLANNED AND DESIGNED FOR POST-MINING LAND USE, IS THE MOST IMPORTANT LONG-TERM ASPECT OF THE MINING PROCESS ON NATIONAL FOREST LAND"

from:

Minerals Policy: Decision-making and the
Minerals Resource USFS Training Course
Mesa, AZ February, 1991

PUBLICATIONS ON POST-MINING LANDSCAPE DESIGN AND LANDSCAPE CHARACTERISTICS

Post-mining landscape design and landscape type are subjects of several Forest Service and Soil Conservation Service publications.

U.S. FOREST SERVICE DOCUMENTS

"National Forest Landscape Management" Vol 2 Ch.1, THE VISUAL MANAGEMENT SYSTEM (1974)

"National Forest Landscape Management" Vol 2 Ch.3, RANGE (1977)

"Creating Land for Tomorrow" 1:(3) Landscape Architecture Technical Information Series (1978)

"Variety Class Criteria for the Great Plains" National Forest Landscape Management Rocky Mountain Region

"Visual Vulnerability of the Landscape: Control of Visual Quality" (1984).

Blunt, W.H. 1980. Management Opportunities for Creating Wildlife Habitat through Surface Mining. Thunder Basin National Grasslands. Douglas Ranger District Douglas, WY

Rumble, M.A. 1989. Wildlife Associated with Scoria Outcrops: Implications for Reclamation on Surface-Mined Lands. Research Paper RM-285 Rocky Mountain Forest and Range Experiment Station Fort Collins, CO

U.S. SOIL CONSERVATION SERVICE PUBLICATIONS

"Landscape Design in Mined Land Reclamation" (1983).

MISCELLANEOUS PUBLICATIONS

Biggins, D.E., Johnson, D.B., Jackson, M.R. Effects of rock structures and condensation traps on shrub establishment. Reclamation Revegetation Research 4:63-71

Fletcher, R. 1990. Wildlife Habitat on the Rocks. Forestry Research West. April, 1990

Shelley, K.J. 1990. Wildlife associated with reclaimed surfaces on active coal mines in the Powder River Basin of Wyoming. Wyoming Cooperative Fishery and Wildlife Research Unit Laramie, WY

Tessmann, S.A. 1982. Habitat reclamation procedures for surface mines in Wyoming. In: Issues and Technology in the Management of Impacted Western Wildlife Thorne Ecological Institute, Boulder, CO

THE LAND AND RESOURCE MANAGEMENT PLAN FOR THE MEDICINE BOW NATIONAL
FOREST AND THUNDER BASIN NATIONAL GRASSLAND (1985)

Guidelines pertaining to reclamation, referenced in the Land and Resource Management Plan (1985) for the Medicine Bow National Forest and Thunder Basin National Grassland, are summarized below:

FOREST DIRECTION (III-3, III-4, III-5)

- Provide characteristic landscapes that satisfy the adopted visual quality objectives.
- Demonstrate grassland management and utilization of the Thunder Basin National Grassland's resources and values in harmony with nature's requirements and behavior to foster long-term economic stability and productivity of the land base and quality of life of the people and communities in the area.
- Manage fish and wildlife habitats, including plant diversity, to maintain viable populations of all known native vertebrate species and meet population objectives of management indicator species.
- Maintain or restore the inherent biological, physical and aesthetic values of riparian ecosystems.

MANAGEMENT REQUIREMENTS (III-12)

- Provide a biological benchmark in man's quest to live harmoniously with extremes of climate, land capability, and economic fluctuations.
- Serve as a model to show how responsive government can positively affect economical, cooperative planning and management at the local level.....
- Demonstrate sound and practical principles of land use for the area.

MANAGEMENT ACTIVITIES (III-19)

- Apply the Visual Management System to all National Forest System lands (Reference Forest Service Manual 2380 and Forest Service Handbook 2309.16 -.25)

MANAGEMENT PRESCRIPTION 4B (III-125)

- Manage habitat for birds and small mammals.
- Manage grasslands and grassland-shrub types to improve wildlife habitat. Improve habitat conditions by increasing forage available to wildlife and enhancing vegetation diversity.

MANAGEMENT AREA DIRECTION (III-231)

SURFACE MINING DEVELOPMENT

- Management emphasis is to encourage and facilitate, where possible, surface mining for coal, uranium and bentonite. The major goal is to improve reclamation procedures and provide improved resource outputs in accordance with the prescription previously, or subsequently applied to these lands.

VISUAL RESOURCE MANAGEMENT

- Plan reclamation to meet the adopted visual quality objective under the post mining management prescription. Treat background areas to maintain form or pattern or form to reflect natural occurrences in the landscape. Study the size, scale and shape of existing forms and repeat them within the appropriate activity.

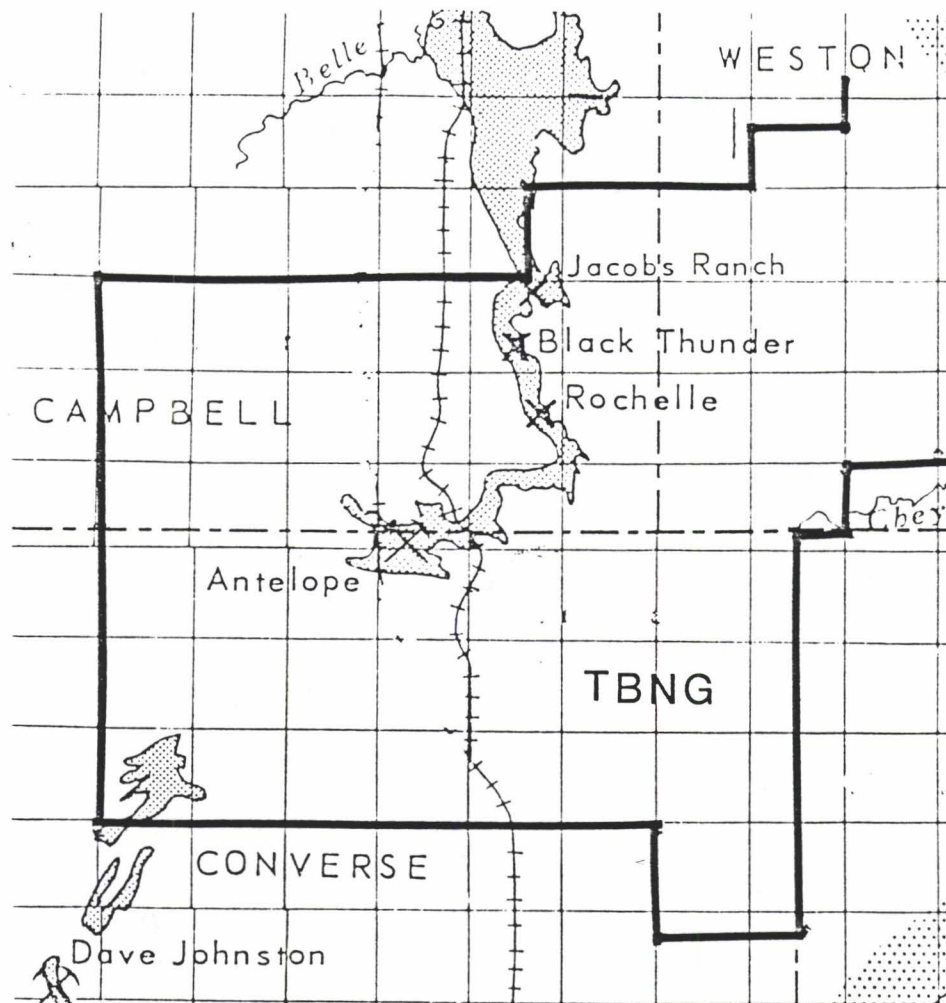
- Provide for orderly rehabilitation of areas identified as unacceptable modification. Ensure that areas currently considered as unacceptable modification are upgraded to the adopted Visual Quality Objective and managed under the short term goal of rehabilitation.
- Use the following short term goals to accomplish rehabilitation: Reduce the impact of form and/or line by reshaping or visually linking areas to create a more natural appearance. Revegetate, reshape land forms, provide forms in scale with natural forms and modify edges of areas to reduce the impact of form and/or line. Reduce the impact of color or texture changes by revegetation, feathered edges and the elimination of management debris."

WILDLIFE HABITAT IMPROVEMENT AND MAINTENANCE (III-232)

- Rehabilitate habitat disturbed through mining activities.
- When available, use spoil piles of rocks to provide habitat for for wildlife.
- Where feasible, design ridges that provide special habitat for antelope and mule deer. Revegetate with shrub, ponderosa pine, juniper or herbaceous species, depending upon which species are best suited to the site.
- Design drainage to favor vegetation needing more moisture such as sedges, rushes and others.
- Prior to mining, prepare alternate suitable replacement sites for sage grouse strutting grounds and nesting areas and sharptail grouse dancing grounds and nesting areas.
- Develop a mitigation plan for any golden eagle nests or roosts which may be disturbed by mining activities.
- Establish cottonwoods, green ash, boxelder or other deciduous trees around ponds and wet sites.
- Where feasible design mining reclamation ponds being developed to support a fishery. (1146MB)

RANGE IMPROVEMENT AND MAINTENANCE (III-233)

1. Establish and maintain vegetation consisting of a mixture of native species or proven introduced species that will enhance the post-mining management prescription.....



Map of the coal mining area of the Thunder Basin National Grassland
Modified from Eastern Powder River Coal Basin of Wyoming FEIS 1972

These are the policies and guidelines which apply to all Forest Service decisions affecting reclamation plans and post-mine land use on the Thunder Basin National Grasslands. Additional guidance is found in the Regional Guide for Forest Service Region 2 (Colorado, Wyoming, Nebraska). The Regional Guide provides the framework for revisions of individual National Forest and National Grassland Land and Resource Management Plans. Biodiversity, the condition and management of riparian ecosystems, visual quality objectives and integrated management of larger landscape units, are important elements of the Regional Guide, under revision in 1991. These issues will receive careful consideration as mine reclamation plans come to the Forest Service for consent.

Specific directives in the Regional Guide include:

1. Consider habitat fragmentation
2. Evaluate the need for linkage and corridors
3. Develop appropriate standards and guidelines to meet identified needs
4. Document how meeting or not meeting multiple-use objectives is affecting biological diversity.
5. Employ active measures to restore elements of biological diversity
6. Avoid oversimplification of the environment
7. Provide for the full variety of life (biodiversity) through ecosystem management
8. Apply ecosystem management at the local, watershed and landscape scales.

In addition to the requirements in the Land and Resource Management Plan (1985), which applies to Federal Surface, mine reclamation plans must also meet specific criteria imposed by the Wyoming State DEQ, the Wyoming Fish and Game Department and the Federal Office of Surface Mining. The intent of this document is not to reiterate already-published regulations of all agencies, but rather to provide an awareness of Forest Service guidelines, a analysis of landscape elements found in the coal mining area and application of these elements to the design of reclamation plans.

LOCATION OF THE COAL MINING AREA

The coal mining area on the Thunder Basin National Grasslands lies in a narrow north-south strip about 20 miles long west of the Rochelle Hills escarpment in Campbell and Converse Counties, Wyoming. Along this axis, coal is near the surface. Where the coal is close enough to the surface to burn, overlying beds of sedimentary deposits have been altered by heat, forming scoria. The scoria landforms are different from the Rochelle Hills sandstones and from the dissected and non-dissected uplands above the coal deposits. The coal mines are located near the scoria landforms because that is where the coal is closest to the surface.

FOREST SERVICE VISUAL QUALITY CRITERIA

The Forest Service uses Visual Variety Classes within Landscape Character Subtypes to characterize landscapes. The Thunder Basin National Grassland, located in the central part of the Powder River Basin, is mapped in the Forest Service Landscape Character Subtype GP6 (Great Plains). GP 6 is a geographic area that includes eastern Wyoming, and the southern half of South Dakota west of the Missouri River, excluding the Black Hills and the Badlands.

Within Landscape Character subtypes are three Visual Variety Classes. These Classes are a way to define the diversity of the visual resource. This diversity is intimately related to the biodiversity of the site. The specific elements in the Variety Classes are useful landscape descriptors against which to compare features of reclamation plans.

All three Visual Variety Classes¹ (Distinctive, Common and Minimal) are found in the coal mining area.

Distinctive Variety Class elements are:

1. terrain which is highly varied and distinctive
2. terrain with unusual configurations and colors
3. vegetation with strongly defined patterns of grasses, saltbush, greasewood, juniper and/or ponderosa pine
4. vegetation forming unique patterns with barren soil or rock.

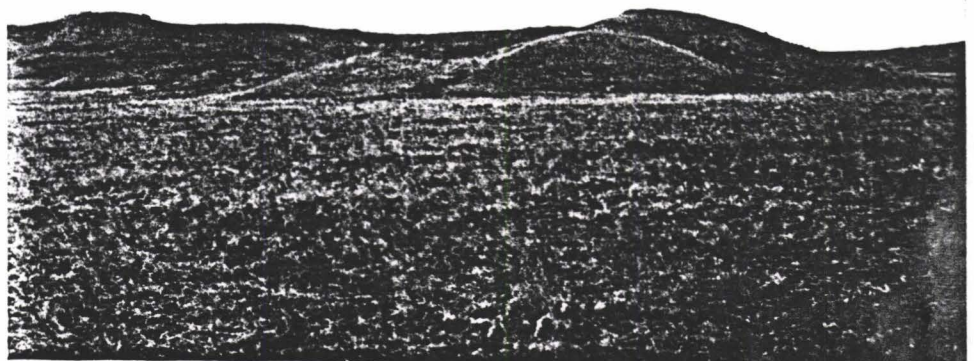
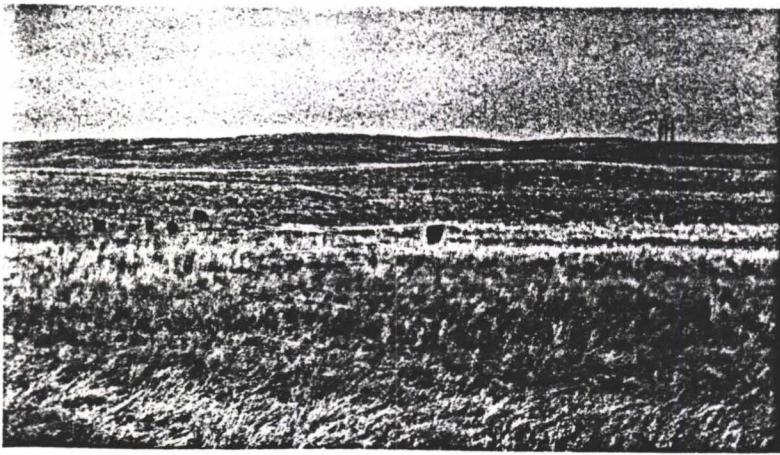
Common Variety Class elements are:

1. moderately varied terrain
2. broad slopes of moderate steepness
3. rounded hills of ordinary landform common to adjacent terrain
4. valleys without strong configuration
5. minor rock outcrops
6. moderately varied vegetation patterns characteristic of riparian areas.

Minimal Variety Class elements are:

1. unvaried terrain with large expanses of flat to rolling undissected landforms that give little scale definition
2. extensive areas of sagebrush or grass.

¹"Variety Class Criteria for the Great Plains Area" - National Forest Landscape Management. 1979 Rocky Mountain Region U.S. Forest Service USDA



LANDSCAPE ELEMENTS

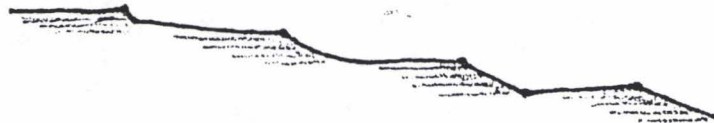
The coal mining area on the Thunder Basin National Grasslands has specific geomorphic, geologic and vegetation properties which create a characteristic landscape. Some attributes of this characteristic landscape, which are suited to the objectives of post-mining land use as expressed by Reclamation Concept Plans, are presented below.

LANDFORMS CHARACTERISTIC OF THE COAL MINING AREA

1. rolling plains



2. dissected plateaus composed of eroding sedimentary strata



3. buttes



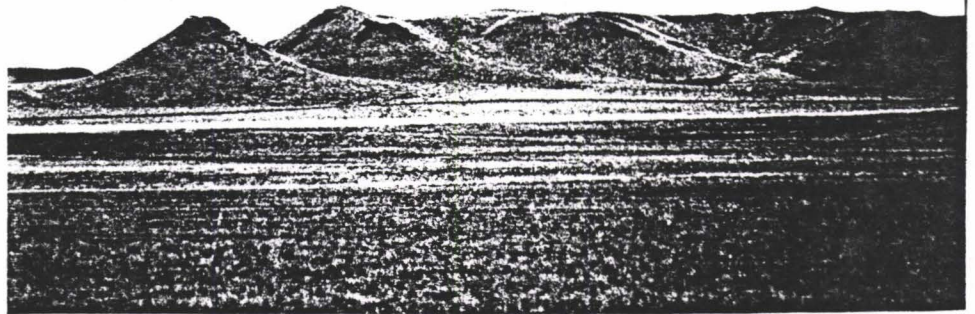
4. conical forms associated with scoria



5. mounded forms associated with softer substrates



These landforms occur at different scales and the smaller forms may be nested in the larger ones. The landforms are controlled by the nature of the geologic substrate and its resistance to the forces of wind and water erosion. With the exception of low topographic positions where sediments temporarily accumulate, the entire landscape is geomorphically eroding and all landforms reflect this process.



UPLAND LANDFORM DIVERSITY

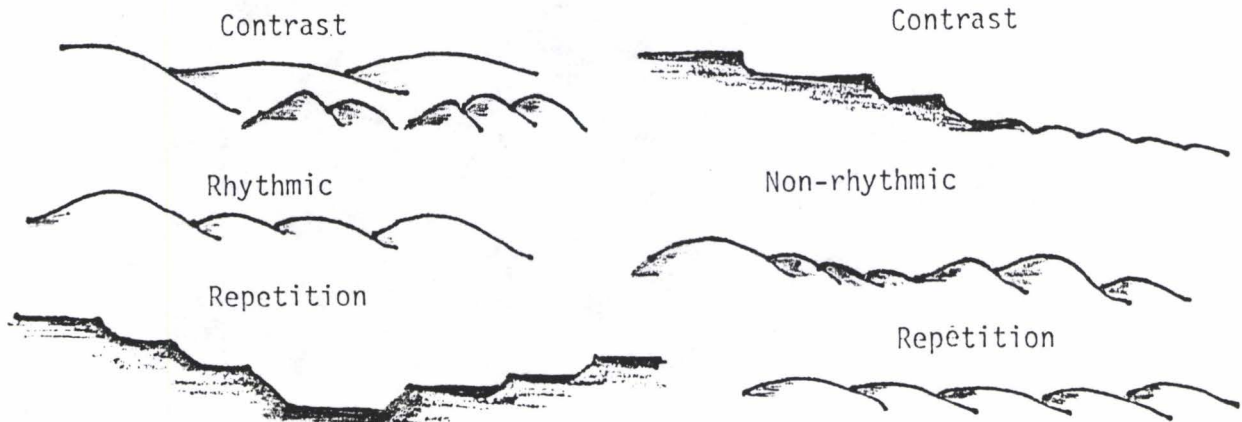
Reclaimed landscapes are formed by deposition of materials and subsequent regrading. Thus, they are created by depositional processes, rather than erosional processes. Part of the challenge for reclamation is to make reclaimed depositional landscapes compatible with surrounding erosional landscapes. In addition, biodiversity goals are easier to achieve if there is diversity in the underlying landforms.

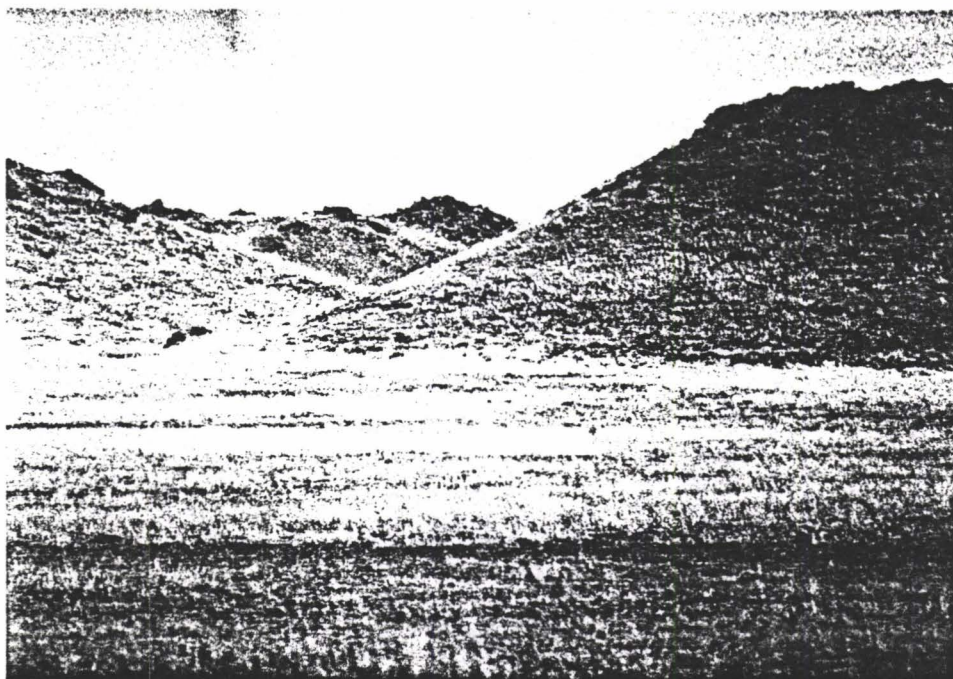
Because of engineering requirements and the malleable nature of the overburden and topsoil materials, reclaimed landforms are usually smooth, of low to moderate relief and have little topographic variety on either small or large scale. Thus their characteristics are mostly of the Minimal Variety Class. The landforms characteristic of buttes, dissected plateaus, scoria hills and the low, mounded forms characteristic of the clay/shale substrates are often not included in the reclaimed landscape. Certain features of these landforms, include elements of the Distinctive Variety Class. Examples include different terrain profiles, colors from clay, shale or rocks and distinctive patterns in the vegetation.

If smooth, low-relief landforms are the only landforms included in the regrading plan, the result is a visually depauperate, repetitious landscape into which it is difficult to incorporate visual and biological diversity. Added elements such as rockpiles may look unnatural and out of scale. The landscape has characteristics of an agricultural field, lacking contrasts of color, texture and form. This landscape may function adequately in preventing soil erosion and producing forage for livestock, but it lacks the attributes needed for multiple-use management objectives which include wildlife habitat.

Incorporation of landform diversity is desirable to improve the basic architecture of the postmine landscape. Enhanced landform diversity may be achieved using the following principles:

1. The scale of the landform should fit the scale of the surrounding landscape.
2. Landform shapes should serve a visual function. This might include contrast of shapes, rhythmic or non-rhythmic sequences of shapes and repetition of shapes.

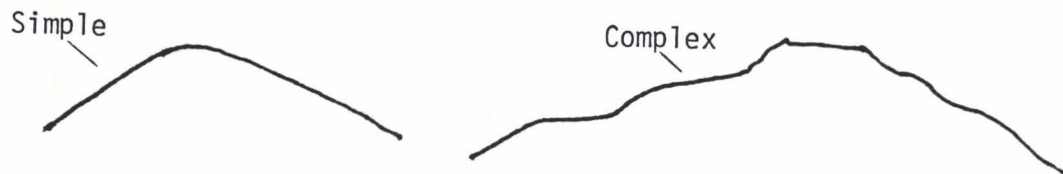




3. Concave areas characteristic of playas are appropriate for upland sites. Flat or concave areas are also appropriate as benches on hillslopes.
4. Hillslope shapes can be convex, concave or flat. The choice of slope form should take into consideration sun exposure, wind exposure, potential for moisture accumulation and the kind of vegetation which will be planted. For example, a concave form on the leeward side of a hill might accumulate snow and serve as a good site for shrub establishment.



Hillslope shapes can also be simple or complex. Complex slopes introduce topographic and visual diversity.



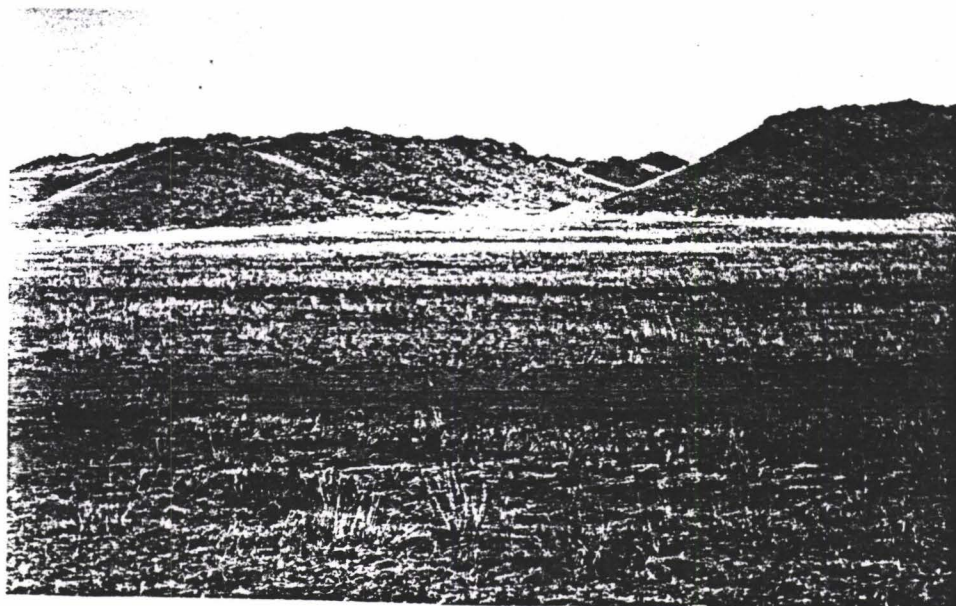
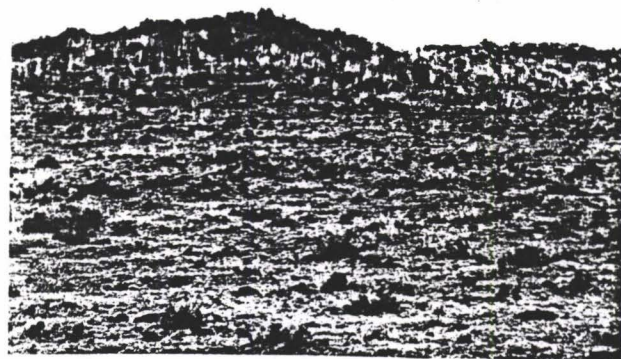
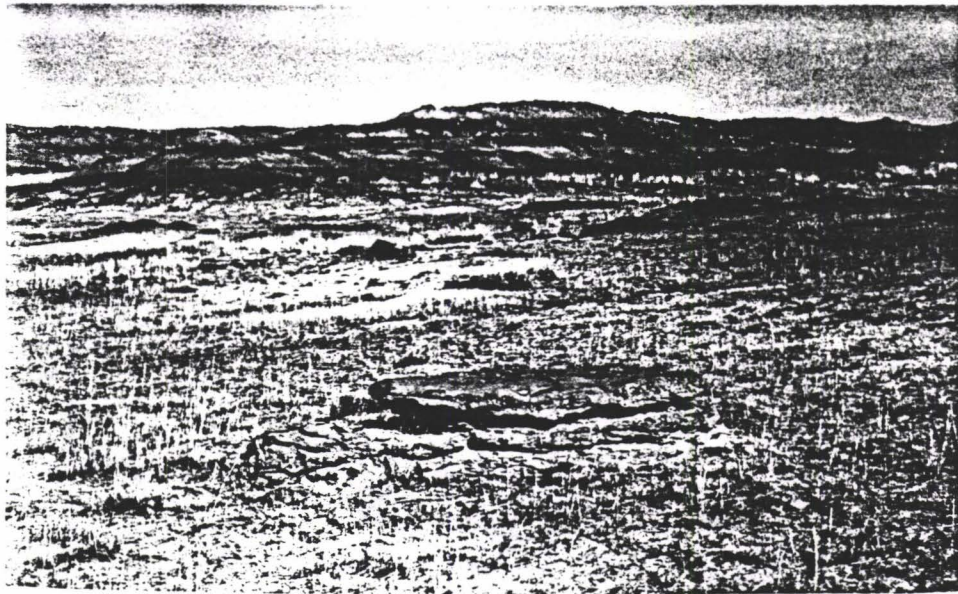
Hillslopes can consist of a series of swales and ridges, which are also expressions of convex and concave surfaces. These forms are nested within the larger pattern formed by the hills and valleys of the total landscape.



5. Created landforms should have the same relative topographic position relationships as those which occur in the natural landscape. For example, groups of conical or mounded forms, near unmined scoria landforms or at the base of hillslopes provide topographic, visual and microclimate variety which encourages vegetation diversity. These created landforms can be complimented by rockpiles and vegetation mosaics. All created landforms should be designed large enough for effective use of seeding equipment.



6. Rocks occur in the natural landscape as rock outcrops or rock ledges. In the natural landscape rock outcrops and rock ledges are erosional features occurring on ridges or hillslopes where resistant strata are exposed. They usually have associated mesic shrub and forb vegetation not found in broad expanses of grassland or sagebrush-steppe. Rock outcrops can be used to add visual variety to the horizon line when placed in hilltop or ridgetop positions. They break the monotonous line of hillslopes, and are especially effective in reclamation if the hillslope has been contoured to include benches and irregularities. Rock outcrops and ledges are more difficult to construct, but give a better end result, especially if mesic shrub plants are included.
7. A common use of rocks in reclamation is to build rockpiles. Rockpiles on valley floors do not have a counterpart in the natural landscape of the Thunder Basin National Grassland. Scoria outcrops have some characteristics in common with rockpiles, but do not occur in the same landscape positions as many manmade rockpiles. Rockpiles that are properly placed in the landscape and meet certain design criteria can create wildlife habitat, add visual variety and create specialized microhabitat areas for plants. Attributes of rockpiles which affect their visual and ecological functions include the type of rocks used, their density and spatial arrangement on the landscape (patch characteristics), their size, shape and grouping, and what kinds and how many mesic shrub species are associated with them. Ongoing research is showing that the dimensions of rockpiles and their relationship to each other and to other landscape features such as shrub mosaics is critical to optimizing their habitat value (Rumble, 1989; Shelley, 1991; Biggins et al., 1985, Tessmann, 1982). Design of individual rockpiles and the landscape patch characteristics of rockpiles must give priority consideration to their functional properties for wildlife habitat.
8. The size and configuration of the rockpiles should compliment the scale of their surroundings and the positions at which they are placed. For example, linear forms go well along hillslopes, while clustered shapes compliment a hilltop. Larger rocks should be placed on the bottom of the pile and all rockpiles should have the lowest rocks buried to 1/3 or 1/2 their height. Rockpiles in low topographic positions should have low profiles, or be built into the slope of a stream channel. A heap of barren rocks in a grassy field provides some extra habitat value, but lacks the visual integrity and broader ecological function of integrated rockpiles or outcrops. While there are requirements for rockpile density, these requirements should not be considered as the only landscape design criterion.
9. Placement of topsoil among the rocks of constructed rock outcrops, rock ledges and rockpiles, and special seeding of mesic forbs and shrubs is an important opportunity for vegetation diversity. Weed control may be necessary during the germination and establishment of the desired mesic species. Irregular edges, peninsulas, or smaller rock piles associated with larger ones in an irregular fashion, are other ways to incorporate structural, visual and functional diversity into rockpiles and rock outcrops.



11. It is desirable to cluster rockpiles on the landscape, not place them randomly. The location of rocks in the backfill process should not be the decision criterion for placement of rockpiles, outcrops or ledges. Use of rockpiles for visual purposes to define space, as focal areas and to add visual structure to the landscape should enhance their ecological function as microhabitat areas, as snow accumulators, as cover for wildlife, nesting sites and denning areas. To accomplish this, attention must be given to the relationship of rockpiles to ridgetops, sideslope drainages, the shrub mosaics and riparian areas. Design expressing these concepts should be included in the Reclamation Concept Plan; implementation of the Concept Plan design will depend on the creativity of and the decisions made by the reclamation personnel and equipment operators as installation proceeds.
12. Highwalls can be approved by the Forest Service on a site-specific basis, where need is defined and procedures from DEQ and OSM regulations are followed.



Natural rock outcrop form
In scale with landscape.

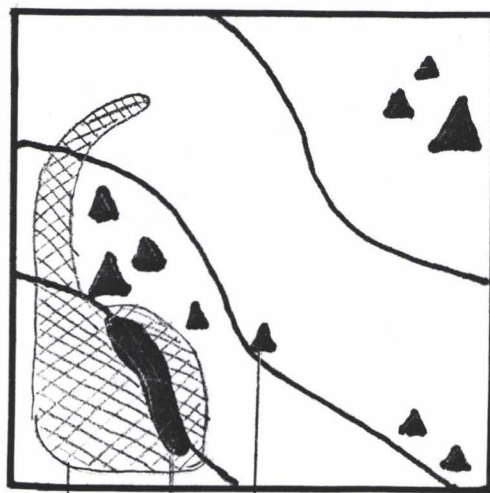


Rocks, in scale, along bank slope.



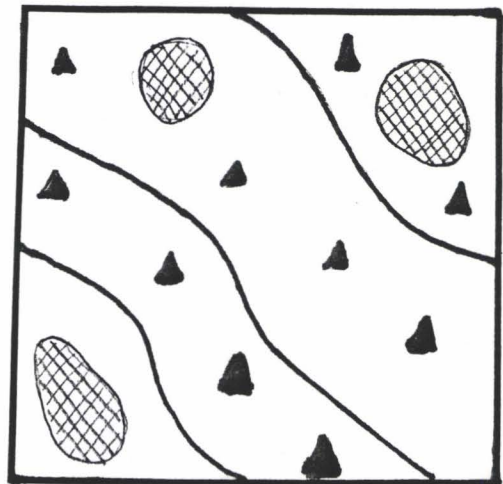
Rockpiles lacking geomorphic fidelity. Out of scale with landscape.

Clustered Design - Preferred

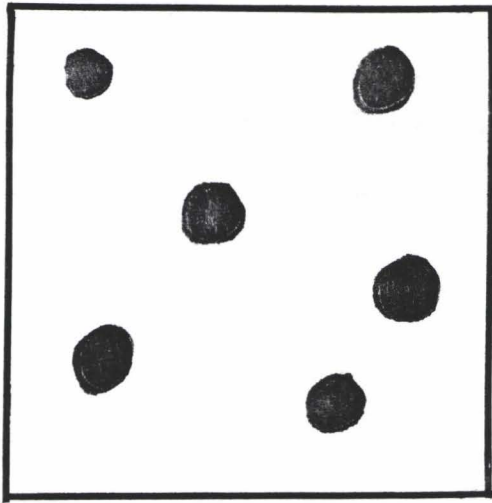


Shrub Mosaic
Rock Outcrop
Rockpile

Open Design - Not satisfactory



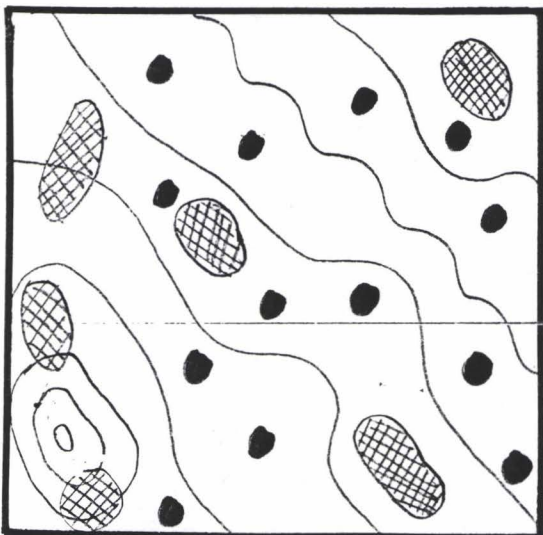
Clustering and integration of rock outcrops and rockpiles with topography and the vegetation mosaic.



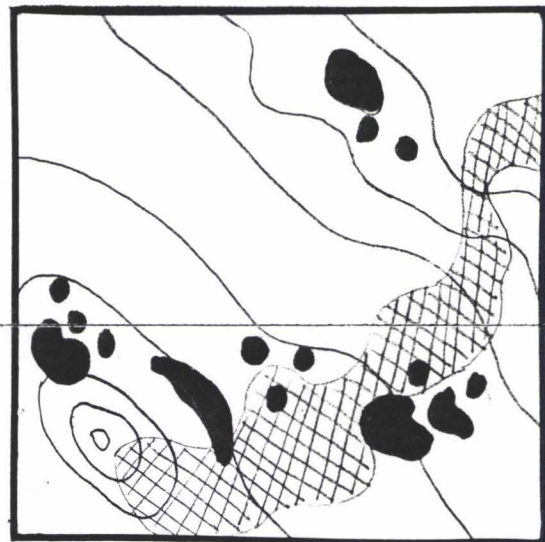
Plan view of rockpiles of about the same shape and size randomly spaced.



Plan view of rockpiles of varying shapes and sizes with satellite rocks near the main cluster. This island chain effect is more desirable than the random pattern.



Shrub patches and rockpiles unrelated to each other and to topography.



Integration of topography, rock outcrop, rock piles and shrub mosaic. A preferred concept.

Some recent publications, based on studies of wildlife behavior in natural and reclaimed rock outcrop/ rockpile landscapes are:

- Blunt, W.H. 1980. Management opportunities for creating wildlife habitat through surface mining. Thunder Basin National Grasslands. Douglas Ranger District Douglas, WY
- Fletcher, R. 1990. Wildlife habitat on the rocks. Forestry Research West April, 1990
- Rumble, M.A. 1987. Avian use of scoria rock outcrops. Great Basin Naturalist 47:625-630.
- Rumble, M.A. 1989. Wildlife Associated with Scoria Outcrops: Implications for Reclamation of Surface-Mined Lands. Research Paper RM - 285 Rocky Mountain Forest and Range Experiment Station Fort Collins, CO
- Shelley, K. J. 1991. Wildlife associated with reclaimed surfaces on active coal mines in the Powder River Basin of Wyoming. 1990 Annual Report. Wyoming Cooperative Fishery and Wildlife Research Unit Laramie, WY
- Tessmann, S.A. 1982. Habitat reclamation procedures for surface mines in Wyoming. In: Issues and Technology in the Management of Impacted Western Wildlife Thorne Ecological Institute Boulder, CO

RIPARIAN LANDFORM DIVERSITY

Riparian areas on the Thunder Basin National Grassland have defineable landform characteristics in addition to their specialized vegetation. On a horizontal scale these include the concave playas and areas around artificial impoundments, which form patches in the upland landscape, the dendritic patterns of collector channels on sideslopes and meanders of creeks on characteristics. For stream channels, sinuosity, width/depth characteristics and bank profiles are important landform considerations.

Stream channels have many properties which make them qualitatively different than uplands. Their shape is linear, they serve as corridors to funnel materials and animal movements, they divide the landscape into sectors which are the mirror image of the sectors created by ridges, and they form a connected web of increasing downstream complexity.

All minesites have some riparian areas. Some of these occur as a function of replacing approximate original contour and drainage, others are new features. More attention needs to be given to design of riparian areas. This may include depressions to accumulate runoff in collector channels, impoundments which take advantage of runoff and ground water as well as special considerations for the larger stream channels.

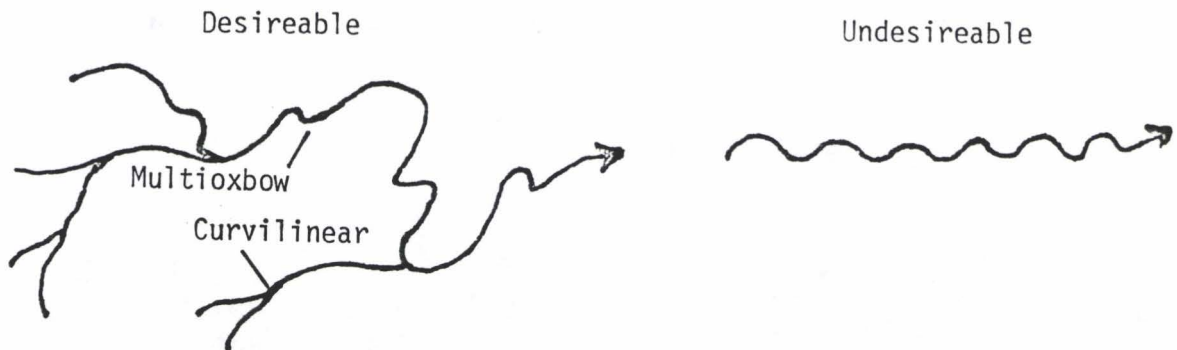


Major riparian areas occur along perennial stream channels or where the water table is high enough seasonally to permit the existence of riparian vegetation, major representatives of which are plains cottonwood, peachleaf willow, coyote willow, greasewood, silver sagebrush, sedges, blue grama, alkalai sacaton and several other grasses. Low topographic areas in draws may support riparian or mesic vegetation because of seasonal runoff accumulation in depressions.

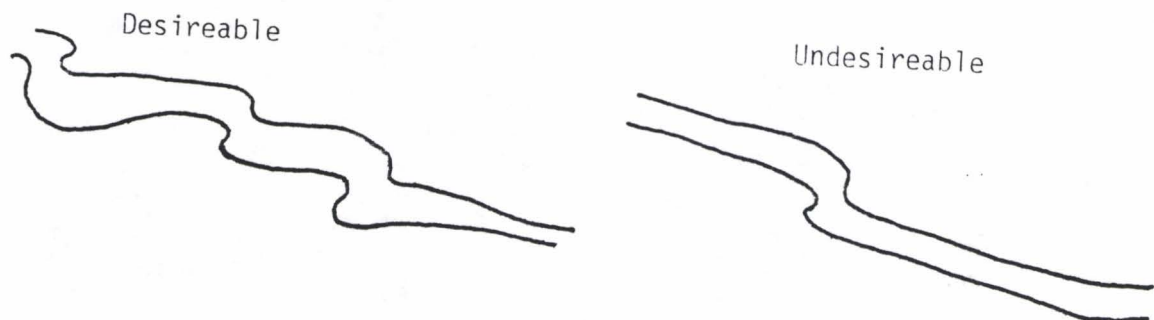
Because of the augmented water availability, the vegetation is of a different texture, color, species composition and vertical structure from the upland and sideslope parts of the landscape. Presence of perennial woody vegetation overstory (cottonwoods or peachleaf willow) and perennial woody understories (silver sage, greasewood, various shrubs or coyote willow) gives riparian areas vertical structural variety not found in any of the upland vegetation types. Riparian vegetation is often strongly zoned because of hydrological controls.

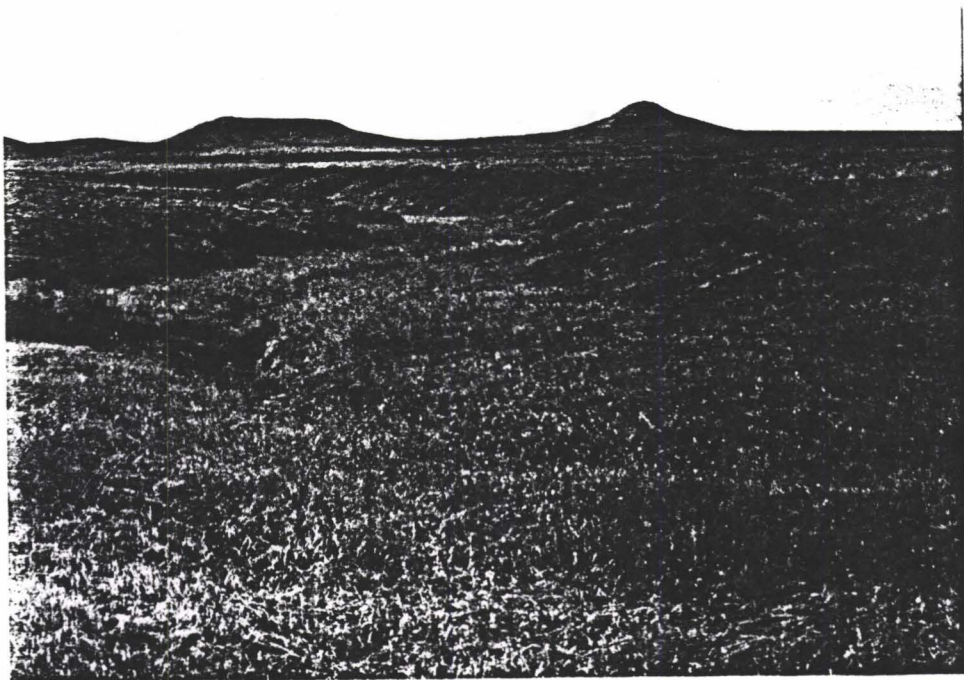
RIPARIAN DIVERSITY DESIGN CRITERIA

1. Channel sinuosity - channels must be designed for stability and capability to handle storm runoff. Variable meander lengths and amplitudes presents a more desirable appearance and can result in more contact edge between riparian and upland vegetation types. Side drainages should have a curvilinear form and a branching pattern. Two channel forms common on the Thunder Basin National Grassland are gradual curvilinear and multioxbow.

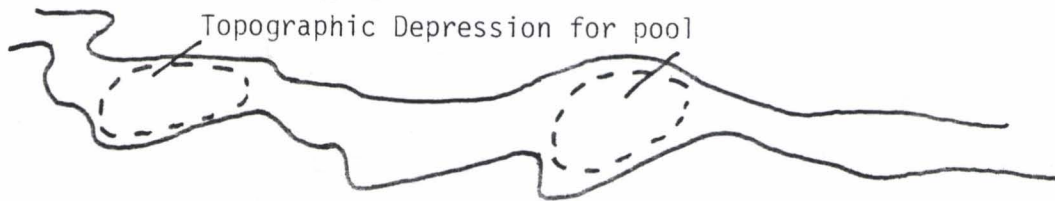


2. Channel width should be variable so the channel does not look like a canal.

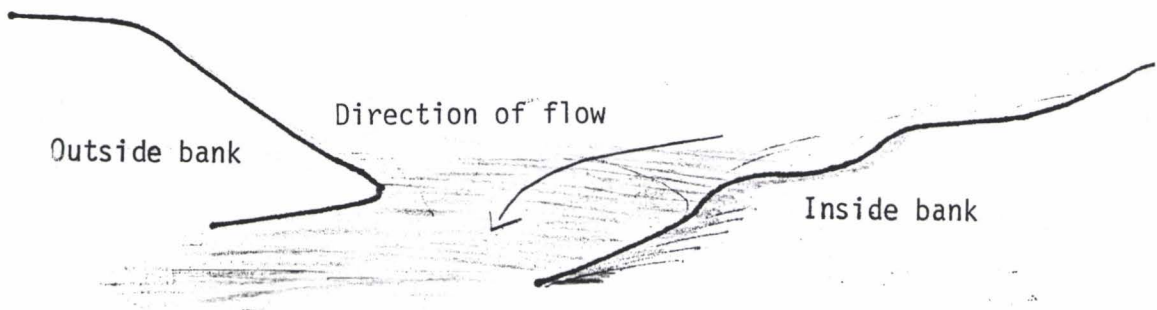




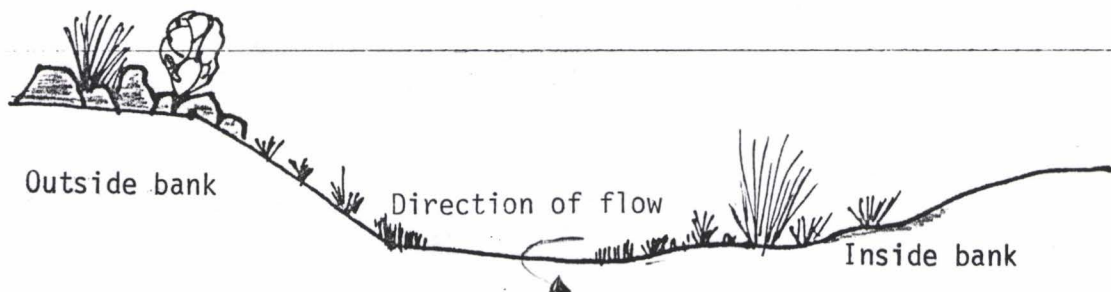
3. Pool sites may be placed in the channel or swales to provide microsites to encourage development of riparian vegetation.



4. Bank heights can vary along the channels. Slopes should reflect natural processes. For example, longer, gentler slopes are characteristic of inside channel meanders.



5. Rockpiles and shrub mosaics should be placed where they might normally occur. For example: outside curves of meanders are places where rocks might be found (since these are actively eroding sites in nature, and where shrub clusters would be well developed). The inside of the curves is a disturbed area due to sediment deposition. It is not a natural site for erosional features.



6. Special consideration needs to be given to spatial configuration of edges of impoundments, shallow water areas and islands these features considerably add to options for biodiversity.

GEOMORPHIC SURFACES AND VEGETATION BIODIVERSITY

Major types of natural geomorphic surfaces in the coal mining area are convex, flat or concave (playa) uplands, dissected sideslopes with benches and rock outcrops, scoria landforms, stream terraces and active stream channels. Each of these geomorphic surfaces has characteristic vegetation, which may be described in terms of plant community types, species composition, life form (vertical structure) and cover (areal or horizontal structure). Landforms create the large-scale architecture of the landscape, into which the structural elements of the vegetation are nested. Just as upland landforms and riparian areas have landscape architectural characteristics, so does the vegetation.

Uplands support grassland or sagebrush grassland (sagebrush-steppe) and playas. Several distinct types of grassland are found in the region. There are also several grass understory types beneath Wyoming big sagebrush in the sagebrush-steppe areas. The species composition depends on the soil type, topographic characteristics, grazing history and fire history. The last two are important factors determining the presence and proportions of sagebrush and grassland patches. Blue grama, western wheatgrass, needle-and-thread, and green needle grass are dominant grass species. Western wheatgrass forms a monoculture in most playas.

Dissected sideslopes, with benches, support more species of forbs and shrubs than the uplands. This surface is eroding more actively and has soil pockets which are scattered and poorly developed. Many plants grow directly in parent material. Although they do not provide significant livestock forage, they provide important wildlife habitat and food. While this eroding topography and specialized vegetation is not feasible to reconstruct to the same extent as upland types, some landform attributes and characteristic species are useful in reclamation. Bench and slope topography and the incorporation of rock outcrops into sideslopes are elements of this geomorphic surface which can be used. Gardner's saltbush, green rabbitbrush and prairie sandreed are useful characteristic species.

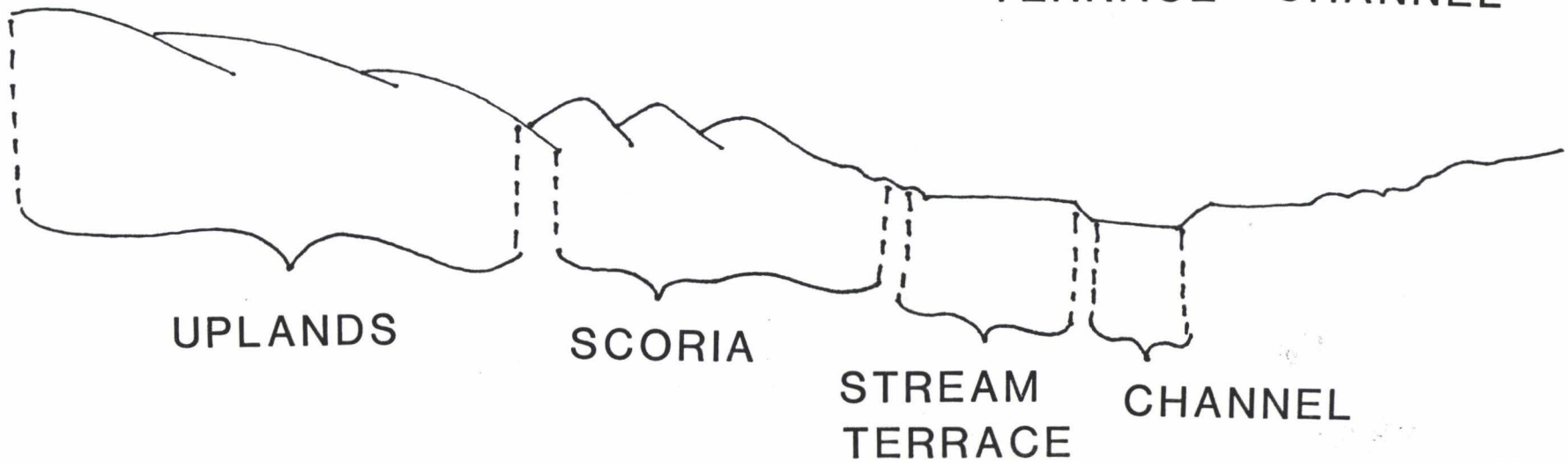
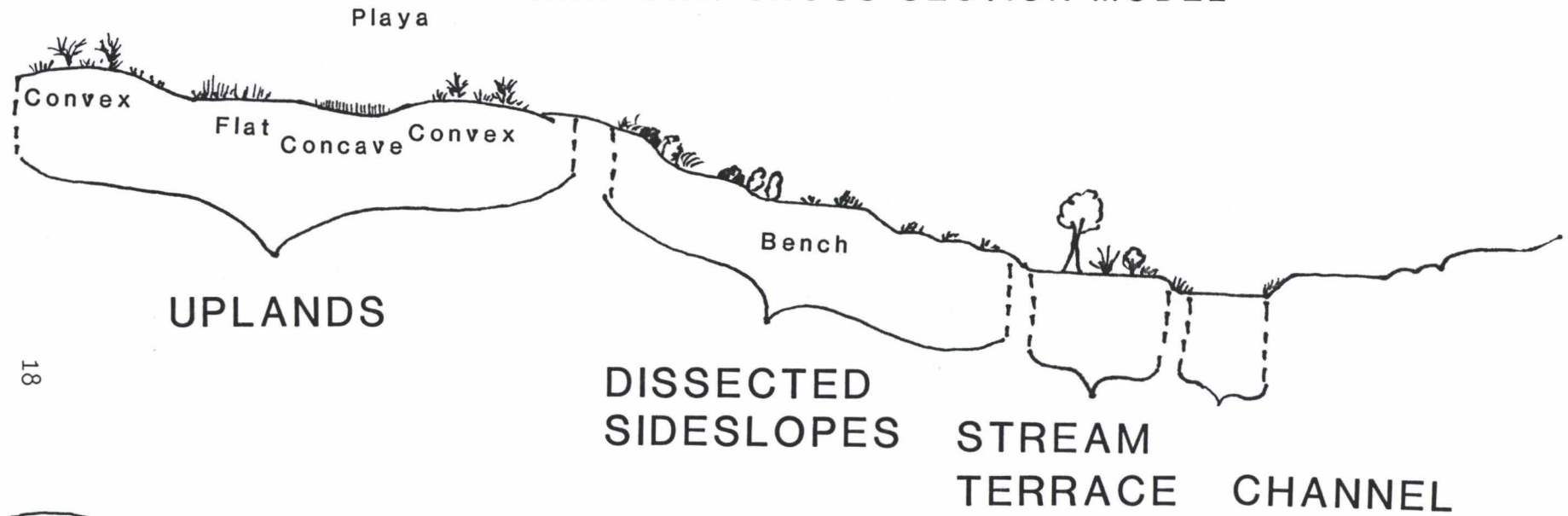
Scoria landforms with associated bunchgrass vegetation and shrub patches within rock outcrops are important wildlife habitat. These exist on a smaller scale than the rolling upland forms, and the hillslopes are steeper and convex. Rock outcrops are numerous and clustered because of their differential hardness and resistance to erosion. Skunkbrush, chokecherry, Gardner's saltbush and green rabbitbrush are important shrubs. Little bluestem, Indian ricegrass and bluebunch wheatgrass are also characteristic of scoria areas.

Stream terraces have the least topographic diversity but the greatest vegetation structural diversity. Plains cottonwood and peachleaf willow form a canopy. Coyote willow, silver sagebrush, and greasewood form a shrub layer. Arkansas rose and snowberry are found as relicts in some areas. The graminoid layer should have blue grama, western wheatgrass, prairie sandreed and green needlegrass, but often lacks these species due to past abuse.

Active stream channels support riparian vegetation where the water table is near the surface. Vegetation consists of sedges, rushes and grasses.

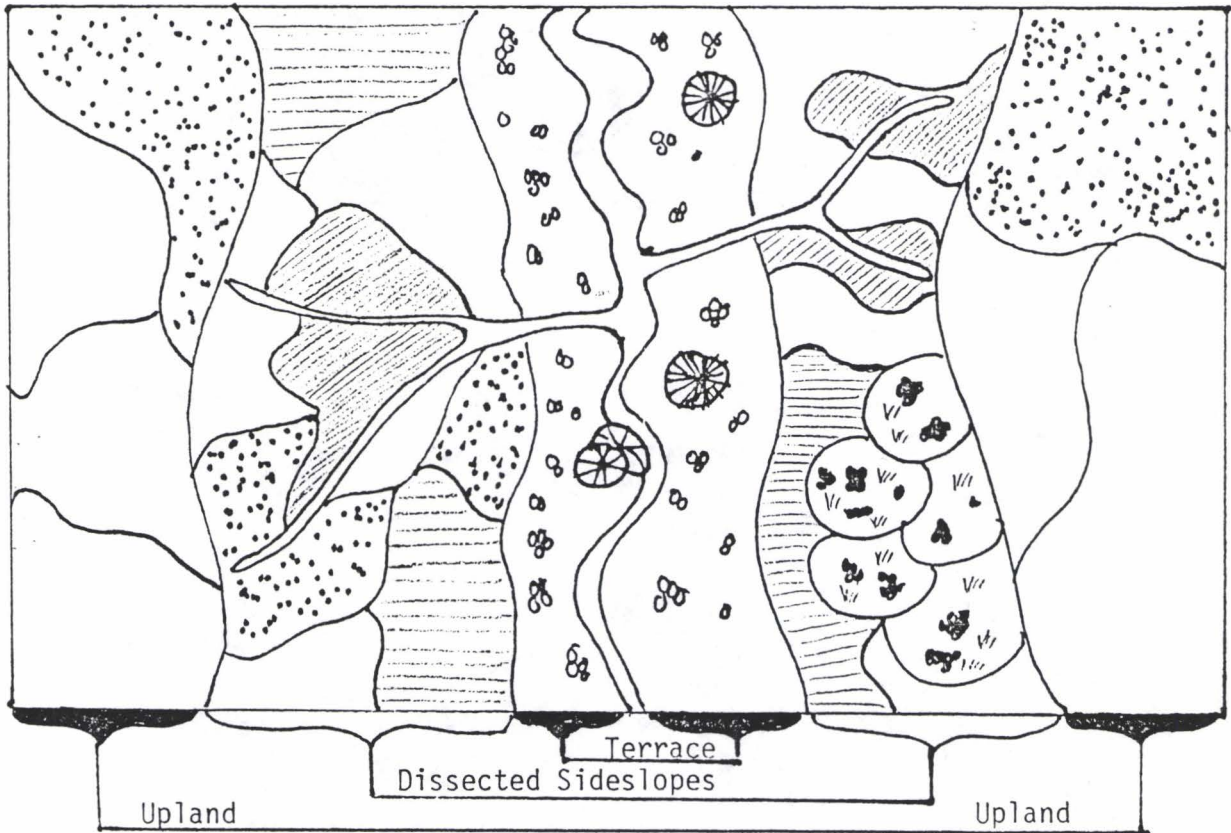
For the purposes of this discussion, the landscape has been dissected into landform elements and vegetation types. These may be distinct on a large scale, but patchy and blended on smaller scales, giving the landscape its character and continuity.

LANDFORM CROSS SECTION MODEL

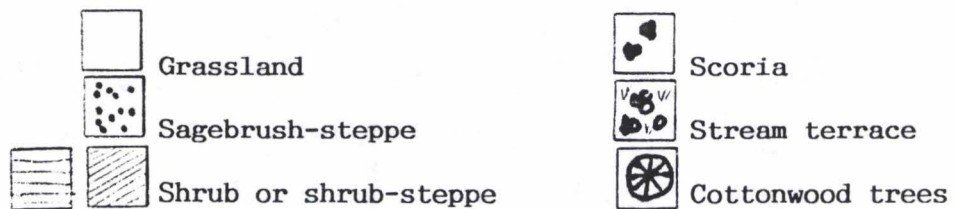


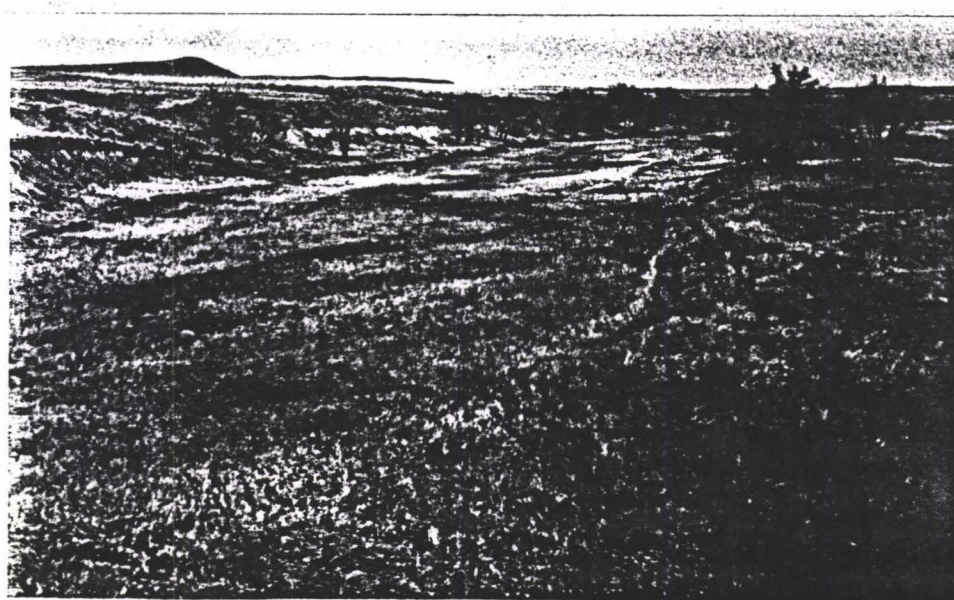
In plan view, the landscape consists of a hierarchy of large patches defined by the geomorphic surfaces, with nested smaller patches defined by vegetation and erosional forms. In this landscape of irregular polygons, drainage features form linear elements with curvilinear shapes and interdigitation. The interplay of shapes, colors and textures in the natural landscape are a result of the interaction of the geologic substrate with geomorphic processes and the development of vegetation.

LANDSCAPE PLAN VIEW MODEL



Elements of this patchy natural landscape can be incorporated into reclamation plans in various combinations to add diversity to the post-mine landscape.





VEGETATION BIODIVERSITY AND LANDSCAPE DESIGN

In addition to the vegetation descriptions provided by the baseline studies for each mine site, the U.S. Forest Service has a classification of vegetation (Thilenius, in press, 1991)¹, for the coal mine area. This classification, identifies 22 common vegetation types in the Upper Cheyenne River Basin in the vicinity of the Rochelle Hills and the coal-mining area. The purpose of this study was to provide a summary of vegetation on the Thunder Basin National Grassland coal mining area useful for the revegetation phase of mine reclamation. Further classification of vegetation for the entire National Grassland is in progress.

The biodiversity of plant species, for these 22 vegetation types, is identified in the Thilenius study and summarized in this document. The Forest Service will use the classification as a reference for evaluation of the pre-mine vegetation studies, revegetation plans and proposed revisions. This classification provides guidance for species composition of the major vegetation which forms common, repeating types characteristic of specific geomorphic surfaces.

Table 1 summarizes major features of these 22 vegetation types which contribute to the characteristic landscape of the coal mining area.

Table 1 Vegetation Types and Geomorphic Occurance (after Thilenius, 1991)

Physiognomic Type	Vegetation Type	Geomorphic Occurance
Deciduous Riparian Forest	Plains cottonwood/Snowberry POSA/SYOC*	Stream Terraces
Coniferous Forest and Woodland	Ponderosa pine/Juniper PIPO/JUSC	Sandstone escarpment
	Ponderosa pine/Bluebunch Wheatgrass PIPO/AGSP	Sandstone escarpment Scoria Hills
	Juniper JUSC	Sandstone escarpment
Grassland	Blue grama BOGR*	Uplands, Benches, Scoria, Stream terraces
	Blue grama/threadleaf sedge BOGR/CAFI*	Uplands, Benches
	Needle-and-Thread/Blue grama STCO/BOGR*	Uplands
	Little bluestem SCSC*	Scoria
Riparian Grassland	Agropyron smithii AGSM*	Playa

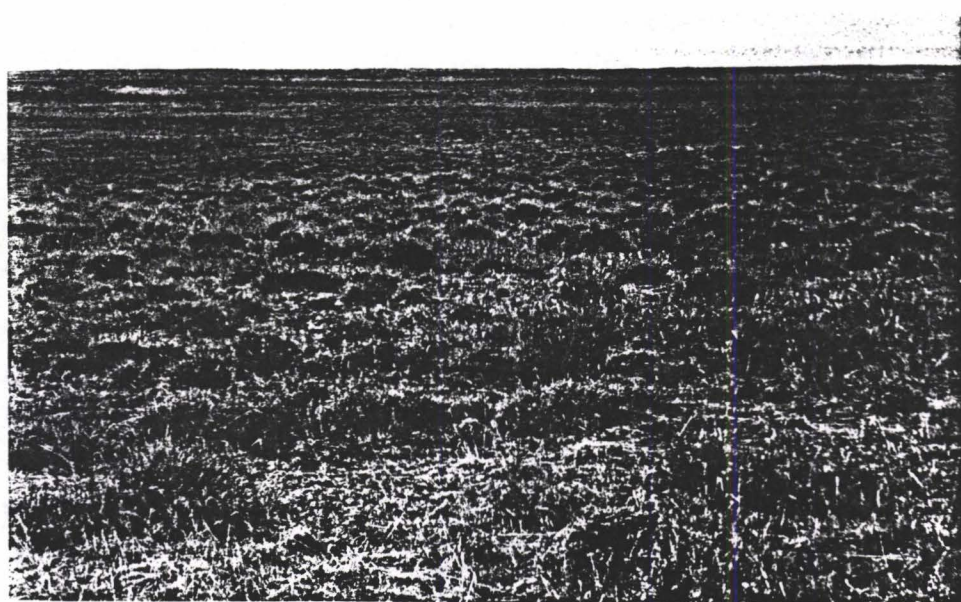
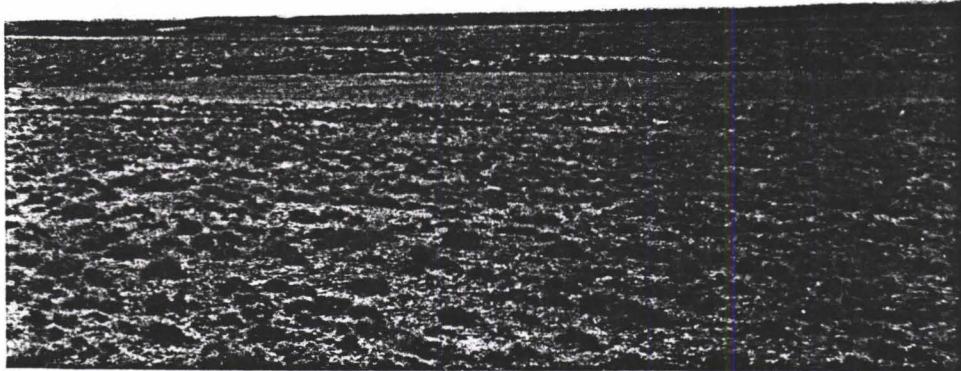


Table 1 concluded

Physiognonic type	Vegetation Type	Geomorphic Occurrence
Sagebrush-steppe (Wyoming Big sagebrush)	Big Sagebrush/Bluebunch wheatgrass ARTR/AGSP*	Scoria
	Big Sagebrush/Blue grama- Bluebunch wheatgrass ARTR/BOGR-AGSP*	Uplands, Scoria
	Big Sagebrush/Blue grama- Western wheatgrass ARTR/BOGR-AGSM*	Uplands, Benches
	Big Sagebrush/Western wheatgrass ARTR/AGSM*	Uplands, Benches
	Big Sagebrush/Green needlegrass ATRT/STVI*	Uplands, Benches
Shrub-Steppe	Skunkbrush/Bluebunch wheatgrass RUTR/AGSP*	Scoria
	Silver Sagebrush/Blue grama- prairie sandreed ARCA/BOGR-CALO*	Sand dunes
	Yucca/Needlegrass YUGL/STCO	Dissected sideslopes
Riparian Shrubland	Silver Sagebrush/Blue grama ARCA/BOGR*	Stream terraces
	Greasewood/Western wheatgrass- Blue grama SAVE/AGSM-BOGR*	Stream terraces
Shrub	Four-winged saltbush ATCA*	Dissected sideslopes
	Green rabbitbrush CHVI*	Dissected sideslopes
Dwarf-shrub	Birdsfoot Sage ARPE	Uplands

The vegetation types with an asterisk(*) are major components of the landscape of the coal mining area, and have characteristic species which appear in many seed mixes included in revegetation plans.

Table 2. Major species from each of the vegetation types listed in Table 1.

Vegetation Type	Characteristic Species
POSA/SYOC	Plains cottonwood Western snowberry Rubber rabbitbrush Silver sagebrush Arkansas rose Western wheatgrass Sandberg bluegrass Green needlegrass Louisiana sagewort Fringed sage
BOGR	Blue grama Wyoming big sagebrush Silver sagebrush Western wheatgrass Sandberg bluegrass Needle-and-thread Copper mallow
BOGR/CAFI	Blue grama Threadleaf sedge Wyoming big sagebrush Silver sagebrush Rubber rabbitbrush Winterfat Needle-and-thread Western wheatgrass Sandberg bluegrass Prairie sandreed
STCO/BOGR	Needle-and Thread Blue grama Western wheatgrass Sandberg bluegrass Prairie sandreed Fringed sage Copper mallow
SCSC	Little bluestem Ponderosa pine Wyoming big sagebrush Blue grama Bluebunch wheatgrass Needle-and-thread Fringed sage
AGSM	Western wheatgrass Sandberg bluegrass Needle-and-thread Western yarrow Louisiana sage

Table 2 contd.

ARTR/AGSP	Wyoming big sagebrush Bluebunch wheatgrass Gardner saltbush Rubber rabbitbrush Juniper Sandberg bluegrass Blue grama Indian ricegrass Fringed sage Copper mallow
ARTR/BOGR-AGSP	Wyoming big sagebrush Blue grama Bluebunch wheatgrass Sandberg bluegrass Needle-and-thread Fringed sage
ARTR/BOGR-AGSM	Wyoming big sagebrush Blue grama Western wheatgrass Needle-and-thread Sandberg bluegrass Fringed sage Scurfpea
ARTR/AGSM	Wyoming big sagebrush Western wheatgrass Silver sagebrush Sandberg bluegrass Needle-and-thread Blue grama Western yarrow Fringed sage Copper mallow
ARTR/STVI	Wyoming big sagebrush Green needlegrass Fourwing saltbush Bluebunch wheatgrass Fringed sage Copper mallow Scurfpea
RUTR/AGSP	Skunkbrush Bluebunch wheatgrass Wyoming big sagebrush Wild currant Rubber rabbitbrush Chokecherry Blue grama Needle-and-thread Sandberg bluegrass Little bluestem Fringed sage

Table 2 concluded

ARCA/BOGR-CALO	Silver sagebrush
	Blue grama
	Prairie sandreed
	Wyoming big sagebrush
	Rubber rabbitbrush
	Needle-and-thread
	Western wheatgrass
	Sandberg bluegrass
	Fringed sage
	Copper mallow
ARCA/BOGR	Silver sagebrush
	Blue grama
	Wyoming big sagebrush
	Rubber rabbitbrush
	Western wheatgrass
	Needle-and-thread
	Prairie sandreed
	Indian ricegrass
	Sandberg bluegrass
	Fringed sage
SAVE/AGSM-BOGR	Copper mallow
	Greasewood
	Western wheatgrass
	Blue grama
	Silver sagebrush
	Sandberg bluegrass
	Sand dropseed
	Alkalai sacaton
	Fringed sage
	Four winged saltbush
ATCA	Wyoming big sagebrush
	Rubber rabbitbrush
	Western wheatgrass
	Louisiana sagewort
	Copper mallow

¹Thilenius, J.T. and G.R. Brown. 1991. Vegetation on Semi-Arid Rangelands, Cheyenne River Basin, Wyoming Rocky Mountain Forest and Range Experiment Station Fort Collins, CO (In Press)

Tables 1 and 2 express a model of vegetation pattern and biodiversity useful for planning revegetation. Certain species, with wide ecological amplitudes, good competitive abilities, and life history characteristics that allow them to survive herbivory pressures, occur in many of the vegetation types. Choices of species to include in mixes must include these considerations as well as considerations of seed price, availability and ease of cultivation. The relationship of landscape design, species diversity and multiple-use objectives should be considered also as reclamation plans are developed and implemented.

When reviewing revegetation proposals, the Forest Service will consider both the types of vegetation proposed for Federal Land and the composition of the seed mixes which will produce these types. Tables 1 and 2 will be used as a guide for biodiversity considerations with regard to both the number and type of vegetation types and their species composition.

Seed mixes, in currently approved reclamation plans, generally include the major native species in the landscape, with the exception of greasewood, three-leaved sumac, bluebunch wheatgrass and little bluestem. These four species, which characterize several important vegetation types, occur infrequently or not at all in revegetation plans, mainly because the riparian areas and scoria grasslands are not included as targets for revegetation types. The limited areas of these types of vegetation available for mine baseline studies, often provided poor examples, resulting in the decision not to include them in reclamation plans because of the presence of exotic species. Playas, and the mesic shrublands characteristic of scoria areas and dissected sideslopes are vegetation types which need more attention during revegetation plan revision. Seed mixes and vegetation type targets need to be evaluated in both the site and landscape contexts to improve overall biodiversity in the reclaimed regional mined landscape.

Species composition is one aspect of vegetation diversity. For grassland patches, the seed mixtures can be varied for different planting areas, to create mosaics within the grassland vegetation. Shrub patches can be integrated into the grass matrix. Size, shape, topographic placement and connectedness are considerations when planning the spatial arrangement of shrub patches.

The shrub mosaic should include a variety of shapes and sizes, including branched or interdigitated patterns as well as solid patches. Thus, in addition to forming a mosaic with grasses, the shrubs can also serve as corridors. Their placement should include consideration of visual function to add variety to the grass background, germination and establishment microsite characteristics and their relationship to rockpiles and riparian areas.

Improved understanding of the landscape ecology the coal mine areas will help in planning a visually diverse, ecologically functional reclaimed landscape. Use of both topographic and vegetation diversity will improve the final product.

Considerations for improving the use of vegetation in reclamation plans, to achieve better biological diversity and visual variety, include:

1. A careful evaluation of the biodiversity of the seed mixes and how they relate to the type of community they will produce.
2. Avoidance of revegetation patches which have regular geometric shapes (square, rectangular), or have long straight edges. Make edges irregular or interdigitated.
3. Changes in the composition of grassland seed mixes so that a grass mosaic results from different plantings.
4. Placement of shrub mosaics where they have the best chance of success. Creation of microsites using rockpiles, small ridges or swales to accumulate moisture and protect shrub plantings from the wind.

5. Varying the species composition for different shrub mosaics.
6. Carefully designing the relationships of the shrub mosaic spatial arrangement to topography, rockpiles, riparian areas and other features of the reclamation plan.
7. Use of subshrubs and forbs as supplements to major grass or grass-shrub mixes for each planting.
8. Design of riparian areas to include zoned vegetation, vertical structural diversity and representation of all major riparian species.
9. Giving woody perennial transplants a reasonable chance of success by providing drip irrigation or regular deep-watering support until they are well-established. Plant woody perennials in clusters. Protect them from herbivory and wind dessication. Mulch all woody perennials with wood chips and crushed scoria.

RECLAMATION PLAN REVEGETATION AND DESIGN ASSESSMENT CRITERIA

The attributes listed below are major items considered as reclamation plans are reviewed:

LANDFORM ATTRIBUTES

- Landform size
- Landform shape
- Landform scale
- Landform diversity
- Landform connectedness

ROCK OUTCROP AND ROCKPILE ATTRIBUTES

- Number
 - Arrangement on the landscape - (patch and cluster characteristics, relationship to landforms and proposed vegetation mosaics)
- Size and shape characteristics (may be evaluated at end of lease period)
- Provisions for topsoil pockets and establishment of mesic shrubs and forbs (may be evaluated at end of lease period)

RIPARIAN DESIGN ATTRIBUTES

- Channel characteristics (may be evaluated at end of lease)
 - Sinuosity
 - Width and bank height diversity
- Habitat diversity
 - Provision for channel pools
 - Islands or shallow water areas for large impoundments

UPLAND VEGETATION ATTRIBUTES

Landscape ecology considerations

- Fit of planned vegetation types to characteristic landscape

- Fidelity of proposed species composition of vegetation types to general model of vegetation type representative of characteristic landscape and baseline studies.

- Patch characteristics (connectedness) of herbaceous vegetation types, rockpiles-outcrops, shrub mosaics and riparian areas.

Seed mix considerations

- Species diversity in seed mixes: grass, forb, subshrub, shrub

- Seeding rates

Shrub mosaic considerations

- Placement of mosaics in relation to topography, in relation to one another and in relation to rock outcrops - rockpiles.

- Shrub mosaic shapes and sizes

- Shrub mosaic species composition (diversity)

RIPARIAN VEGETATION ATTRIBUTES

Landscape ecology considerations

- Placement of tree and riparian shrubland mosaics in relation to each other and riparian topography.

Species diversity considerations

- Provision of mesic shrubs for riparian shrublands and for shrub plantings in draws or other areas where moisture is augmented by topographic position or snow accumulation

- Species composition of seed mixes for graminoids and shrubs

- Species composition for riparian plantings

Establishment support for riparian plantings

- Planting methods - soil conditioners, planting dishes, mulch, berms

- Prevention of competition from grasses

- Protection from herbivory

- Provision for supplemental irrigation - deep-watering or drip system

Coal mining reclamation on the Thunder Basin National Grasslands in the 1990s has a decade of experience to build on. Models of the landscape ecology of the Thunder Basin National Grassland coal mining area and effective and improved ways to implement the construction and revegetation of the reclaimed landscape will assist in the production of an attractive and useful post-mining landscape which will meet the multiple-use objectives of the Land and Resource Management Plan for the Thunder Basin National Grassland.